Paper No. **971018**

PREPRINT

Title:

Transportation and Fuel Technologies Performance Analysis Methodology

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Transportation Research Board
76th Annual Meeting
January 12-16, 1997
Washington, D.C.

INTRODUCTION

The basis for the development of this paper results from a five-year transportation research and development plan prepared as required by Section 2021 of Public Law 102-486, the Energy Policy Act of 1992 (EPACT). The plan described an overall framework within which research and development (R&D) is conducted by the Department of Energy's Office of Transportation Technologies (Ref. 1). The plan also provided the basis for the results developed in support of the Office of Energy Efficiency and Renewable Energy's Quality Metrics (QM) and Strategic Principles initiative.

The Office of Transportation Technologies (OTT) R&D framework was defined as a result of an intensive analytical effort to assess societal benefits relative to Federal government budget expenditures that would occur throughout the estimated duration of a variety of R&D programs. In an effort to measure individual technology and alternative fuel impacts, estimates are calculated by technology and fuel type. As a result, modeling and assessment methodologies reflect a detailed process designed to allow for sensitivity analysis on a wide range of variables.

The methodology has been applied to nine advanced technologies and alternative fuel types which represent the principal program activities of the OTT:

Alternative Fuels and Vehicles

1. Biofuels for use in flex-fuel and dedicated alcohol fuel light duty vehicles
2. Alternative Fuel Vehicles including CNG and LPG fueled light duty vehicles

Electric Vehicle Technologies

3. Electric Vehicle R&D
4. Hybrid Vehicle R&D
5. Fuel Cell R&D

Transportation Material Technologies

6. Ceramic Materials R&D
7. Lightweight Materials R&D

Combustion Engine R&D

8. Light Duty Engine R&D
9. Heavy Duty R&D

Analyses consider a time frame that spans 1995 through 2020. The end date was selected in order to enable consideration of the long time period needed for advanced vehicles to penetrate the overall vehicle fleet, and to consider the potential benefits of longer-term technologies such as fuel cells.

Strategy evaluations consist of a three-step process that addresses market penetration potentials, overall vehicle fleet transitions and the resulting energy and environmental benefits, and impacts on the economy as measured by gross domestic product (GDP) and employment growth. Completed analyses emphasized light duty vehicles (LDVs), especially in personal use applications. Current efforts are placing more emphasis on heavy vehicle market characteristics and benefits potentials.

TECHNICAL CHARACTERISTICS

A range of technical and R&D Program characteristics were defined quantitatively for use in the analysis process. Particularly important characteristics included:

- C **Year of expected commercial introduction of a technology** - For end-use vehicle technologies, this was defined as achieving commercial production of more than 20,000 vehicles per year.
- C **Year of zero Government funding** - this time period is defined as the time at which R&D support would end, an indication that commercial introduction is imminent,
- C **Relative cost of advanced technology** vehicle and alternative fuel compared to conventional vehicles and RFG,
- C **Range between fuel refills** - also defined relative to ICE vehicles,
- C **Emissions levels** of criteria pollutants,
- C **Type of fuel**, and
- C **Fuel price.**

Characteristics were estimated based on the assumption that DOE program budget levels would be adequate to assure technological success at a ninety percent (90%) probability level.

Inputs for vehicle and fuel attributes are generated through surveys of OTT program managers with review from industry and academia. Comparisons are also made against advanced vehicle estimations obtained through the Delphi, the Electric Vehicle and Hybrid Vehicle Total Energy Cycle Analyses, and other outside sources. Certain vehicle and fuel characteristics (i.e. price and efficiency) are taken from the AEO 96 Reference Case (Ref. 2). The results of this analysis are indicated in Exhibit 1.

External peer reviews comprise an important part of the analysis methodology. External peer reviews were performed for the Quality Metrics efforts by the Energy Information Administration, Arthur D. Little, Inc., and Applied Energy Systems, Inc.

Vehicle assumptions relating to biomass-derived fuels that were used to complete the analysis include the following:

- Both dedicated and flex-fuel vehicles have equal cost to conventional vehicles
- Biomass vehicles have the same characteristics as conventional vehicles except for fuel economy
- Dedicated ethanol vehicles have fifteen percent (15%) higher fuel economy than conventional vehicles, flex-fuel vehicle have the same fuel economy as conventional vehicles.
- The amount of ethanol used in flex-fuel vehicle is determined endogenously by the vehicle choice model and is determined primarily by price.

For this analysis it was assumed that flex-fuel and dedicated fuel vehicles would use only ethanol made from biomass. Exhibit 2 illustrates the assumed ethanol retail prices per gallon of gasoline equivalent (125,000 Btu). All prices are reflected in 1995 dollars. Ethanol costs were taken from program goals. Mark-up, Distribution, and Federal Tax were taken from the 1996 Annual Energy Outlook. The Federal Tax goes down as a result of using constant dollars and assuming that the tax is not increased to keep pace with inflation. The State Tax is the average state tax charged for a gallon of gasoline.

EXHIBIT 1:

TECHNOLOGY CHARACTERISTICS/INPUTS FOR OTT TECHNOLOGY BENEFITS ANALYSIS - QUALITY METRICS 1997

TECHNOLOGY	YEAR OF INTRO./ ZERO GOVT. FUNDING	VEHICLE COST RATIO	FUEL ECONOMY RATIO	RELATIVE RANGE	EMISSIONS (TAIL PIPE)	TYPE OF FUEL	FUEL PRICE. $/GAL. (Equiv.)	COMMENTS
ELECTRIC	1998	1.6	3.3	0.33	0	NON-	1.79	Point of use
	2003	1.1	5.2	0.67		PETRO.	1.81	
ADV. DIESEL	2002	1.1	1.25	1	TIER II	D.F. NO. 2	$1.20	Fuel economy ratio
	2005	1.02	1.35	1		D.F. NO. 2	$1.28	on a BTU basis
HYBRID 1	2002	1.2	1.7	1	TIER II	GASOLINE	1.34	Also can use other liquid or gaseous
	2005	1.02	2.1	1		GASOLINE	1.38	state fuels.
HYBRID 2	2006	1.2	2.5	1	TIER II	GASOLINE	1.39	Also can use other liquid or gaseous
(PNGV)	2015	1.07	3	1		GASOLINE	1.42	state fuels.
FUEL CELL	2007	1.45	2.1	1	ULEV	METHANOL/	1.27	Also can use hydrogen.
	2012	1.1	3	1		ETHANOL	1.25	
COMPRESSED	1995	1.2	1	0.7	TIER II	NATURAL	0.69	Conformable tanks
NATURAL GAS	2003	1.05	1	0.9		GAS	0.95	assumed.
LPG	1995	1.015	1.015	1	TIER II	PROPANE	1.07	Conformable tanks
	2003	1.013	1.013	1		PROPANE	1.17	assumed.
ETHANOL-	2005	1	1.15	0.9	TIER II	ETHANOL	1.27	Optimized engine
FUELED	2010	1	1.15	0.9		ETHANOL	1.25	
LIGHT WEIGHT	2002	1.07	1.21	1	TIER II	GASOLINE	1.34	30% weight
(ALUMINUM)	2010	1.03	1.21	1		GASOLINE	1.4	reduction.

NOTE 1: Mature" is defined as the time of "zero Government funding".

EXHIBIT 2:
ETHANOL PRICE ASSUMPTIONS

$ per gallon (Gasoline Equivalent Basis)	2000	2010	2020
Ethanol Cost	1.29	0.96	0.86
Mark-up	0.13	0.13	0.13
Distribution	0.05	0.05	0.05
Federal Tax	0.15	0.11	0.11
State Tax	0.19	0.19	0.19
Total	1.81	1.44	1.34

ANALYTICAL MODELS USED IN THE OTT PLANNING PROCESS

The Quality Metrics methodology utilizes a variety of computer-based analytical tools and requires inputs for both advanced vehicle and alternative fuel technologies. Currently, the analytical tools utilized by OTT are not integrated into a comprehensive system. Instead, the models are implemented throughout the analytical process and include the following:

- The Alternative Vehicle Sales (AVS) model,
- Heavy Duty Market Penetration Model,
- Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model,
- Integrated Market Penetration and Anticipated Cost of Transportation Technologies (IMPACTT) Model, and
- Argonne Multi-sector Industry Growth Assessment Model (AMIGA).

In addition to the models and other analytic sources, OTT conducts various inquiries into consumer acceptance of alternative fuels and advanced vehicles. Through questionnaires and other information collection tools, increased understanding can be gained regarding consumers willingness to purchase these new technologies, often providing feedback as to why they like or dislike a specific technology or fuel. OTT also has access to the Truck Inventory and Use Survey (TIUS) which provides detailed information on truck stocks and usage.

VEHICLE CHOICE ANALYSIS

Market penetration estimates rely on the use of the Alternative Vehicle Sales model version 8.1 (Ref. 3). This model is a discrete choice, multinomial logit model designed to simulate the household market for alternative-fuel light-duty vehicles. The model forecasts, to the year 2020, the future sales of alternatively fueled light-duty vehicles by technology and fuel type. These estimates are based on consumer derived utilities related to a set of vehicle attributes that are associated with each of the different technologies.

The vehicle demand function used in this model is based on a utility-maximization theory which defines the consumer demand for alternative vehicles as a function of the attributes of these vehicles and the fuels they use. The total utility of each light-duty vehicle technology and fuel is determined by the sum of the attribute utilities of that vehicle. The market share penetration estimates for the different technologies are a function of each technology's total utility compared to the total utility of other vehicles and technologies in the market. The technology's total utility is calculated by summing attribute input values that have been determined by multiplying the attribute by its corresponding utility value.

AVS estimates the market share penetration of alternative-fuel light-duty vehicles for twelve individual technologies. The twelve vehicle technologies contained within the model can be described as follows: conventional vehicles with internal combustion engines (ICEs) operating on gasoline; conventional vehicles with ICEs operating on diesel; conventional vehicles with advanced diesel engines, light weight aluminum intensive conventional vehicles; conventional vehicles with flex-fuel capability operating on a variable mixture of gasoline and alcohol fuels (ethanol or methanol); ICE dedicated alternative fuel vehicles operating on either alcohol (ethanol or methanol) or gaseous fuels (compressed natural gas or liquid propane gas); electric vehicles, hybrid electric vehicles with ICE's or gas turbine engines and electric motors; and fuel cell vehicles with on-board ethanol reformers. Only technologies for which there are OTT programs are included in this analysis.

For each technology, the model considers a set of generic vehicle attributes representative of all vehicles within that technology and a set of fuel attributes corresponding to that technology.

As indicated in Exhibit 1, the vehicle attributes include:

1) Vehicle purchase price in 1990 dollars,

2) Vehicle efficiency in equivalent miles per gallon of gasoline,

3) Tailpipe emissions, and

4) Range, defined as miles traveled before refueling is required.

The fuel attributes include:

1) The fuel price estimated in dollars per gallon of gasoline equivalent, and

2) The availability of the fuel.

Demographic characteristics included in AVS are segmented either: by income, education, and geographic area; or by number of vehicles per household (0-1, 2, and 3 or more), education, and geographic area. In this analysis, market penetration estimates are determined by income, education, and geographic area. These characteristics are defined as follows:

C Income: less than $35,000 per year or greater than $35,000 per year,

C Education: college degree or no college degree, and

C Geographic: Clean Air Act attainment area, or Clean Air Act non-attainment area.

The model is designed to estimate vehicle market shares for each of the eight classes using the relevant consumer preference coefficients and vehicle and fuel attributes for each individual class. In terms of consumer preference, the difference in educational class is the most important factor because separate choice models were estimated for each of these two groups; the income classes are important in terms of gasoline vehicle preference due to the alternative fuel constant for high income; and differences in preferences due to geography reflect the value placed on reduced emissions; households outside non-attainment zones are assumed to place half as much importance on local-area emissions.

Aggregate market penetration is estimated as a weighted average of the eight individual class shares. Exhibit 3 below details the population distribution by class for the weighted calculation. It is assumed that this distribution remains constant over time.

EXHIBIT 3: POPULATION DISTRIBUTION BY CLASS

	Non-attainment	Attainment	Total
High education, High income	13%	6%	19%
High education, Low income	7%	3%	10%
Low education, High Income	18%	9%	27%
Low education, Low income	29%	15%	44%
Total	67%	33%	100%

AVS also includes two vehicle/fuel attributes that are calculated endogenously, vehicle availability and fuel availability. These are also the new supply-side components that have been added to the model. Vehicle availability is defined as the number of individual make/models offered for sale within that class. This is determined in each forecast year by the demand for that class in the previous year. It is assumed that manufactures enter the market if the demand for that technology, divided by the current number of make/model offerings, exceeds a given threshold (20,000 vehicles per year). This approach to estimating the number of vehicle model offerings results in the number of models tracking the demand for vehicles. As a result, when demand increases, the number of makes and models increases which in turn increases demand.

A similar dynamic is used to calculate fuel availability. As vehicles that are capable of using a particular fuel are purchased, potential fuel demand grows. Fuel suppliers are assumed to enter the market when the potential demand achieves a threshold level. In each forecast year the potential demand for each fuel is estimated, and checked against available supply (constrained by retail refueling capacity). If fuel demand is constrained by retail supply capacity, then in the following year, additional refueling stations open such that the new number of stations become sufficient based on last years demand. As a result, when stations increase so does fuel availability which in turn increases vehicle demand, which increases fuel demand.

Consumer derived utilities for attributes described in the AVS model were estimated from data collected in a 1991 stated preference survey conducted by Bunch, et al, in the South Coast Air Basin of California (Ref. 4). The attribute coefficients were derived from analyses using a discrete choice multinomial logit model. In their analyses, Bunch, et al, estimated attribute coefficients and constant terms for four technology types: 1) dedicated alternative fuel vehicles, 2) multiple fuel vehicles, 3) electric vehicles, and 4) hybrid electric vehicles. In order to relate the results of the research by Bunch, et al, to the twelve technologies evaluated in the OTT planning process, several simplifying assumptions and judgment-based extrapolations were made.

It is also important to note that a major limitation in estimating the potential household market penetration of alternative vehicle technologies is the lack of *revealed preference data.* Revealed preference data is gathered from actual consumer response in the market place. Currently, there are only a limited number of alternative-fuel technologies commercially available. Although purchase and use data are being collected on these vehicles, they are primarily owned by fleet operators, reflecting the desired attribute utilities of that market.

The output of the AVS simulations are estimated market shares of new car sales (in percentages) of the alternative vehicle technologies, and the conventional vehicle technologies. The results are applicable to consumer, personal use vehicle purchase decisions. Exhibit 4 is a representative output illustrating market penetrations of new vehicle sales generated using AVS. Market penetration estimates are based on vehicle attribute values illustrated in Exhibit 1.

EXHIBIT 4:

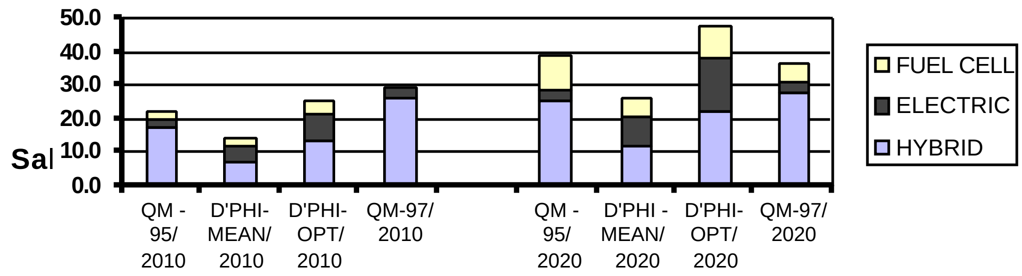
MARKET PENETRATION ESTIMATES

Technology	Market Penetration of a % of New Vehicle Sales		
	2000	2010	2020
CNG/LPG Vehicles	3.7%	1.1%	0.9%
Alcohol Vehicles	40.7%	15.6%	15.2%
Electric Vehicles	2.5%	2.9%	2.5%
Fuel Cell Vehicles	0.0%	3.9%	13.7%
Heavy Duty Vehicles	0.0%	66.0%	100%
Hybrid Vehicles	0.0%	27.6%	26.5%
Advanced Diesel Vehicles	0.0%	9.5%	7.5%
Aluminum Vehicles	0.0%	11.5%	9.9%

Source: Quality Metrics Analysis (Compiled by John Maples, U.T., February 1996)

The market penetration estimates generated through the use of the AVS model has been analyzed in comparison to other recent market research activities. The results of one assessment are indicated in Exhibit 5. This exhibit indicates four market penetration scenarios: Quality Metrics 1995, the mean estimates from a recently completed Delphi survey, the optimistic estimates from a recent completed Delphi survey, and Quality Metrics 1997 (Ref. 5). The bar chart shows two clusters of penetration estimates: year 2010 (left side of chart), and year 2020 (right side of chart). Each bar is made up of market penetration estimates for three technologies: hybrid, electric, and fuel cell; though fuel cells are projected to not be penetrating the marketplace in the year 2010.

EXHIBIT 9:
Market Penetration Comparisor



It can be seen that the AVS-generated penetration estimates are more optimistic than the Delphi respondents for the year 2010. However, the optimistic Delphi respondents provided the greatest estimate of market penetration for the year 2020.

The market penetrations indicated in Exhibit 5 are aggressive, and reflect assumptions concerning funding levels, and funding level consistency which may or may not be realized. However, it is interesting to compare these estimates to other historical examples of fuel switching that have occurred in the U.S. A recent analysis contained in Reference 6, cites six examples spanning the shift from wood to coal in railroads, to the transition from leaded to unleaded gasoline in light-duty vehicles. A substantial part of these transitions were shown to have occurred during fifteen year periods. In some cases the fifteen years elapsed after an initial market penetration threshold had occurred (e.g. coal to oil in ground transportation and gasoline to diesel in public transportation); and in others the growth occurred after initial market entry (e.g. coal to diesel railroads).

In view of the preceding, it is observed that the AVS results have provided market penetration estimates that are generally consistent with other recent forecasts, and that they are consistent with historical fuel switching precedents.

The Heavy Duty Market Penetration Model (HDMP) model was developed to provide a user-friendly, albeit somewhat simplistic tool, to estimate the potential market impacts of a new technologies on the heavy and medium duty truck market. The market impact is measured as estimated market penetration in percent of new vehicles having the new technology as an installed item. The model makes projections annually to year 2020.

Initial research has revealed that in the heavy and medium duty truck markets, vehicles are frequently purchased to unique specifications provided by the buyer. Often, these vehicles are produced using components manufactured by several different companies. In most cases, vehicle engines and drive trains are supplied by manufacturers separate from those building the truck/tractor bodies and assembling the final product. As a result, it is assumed that vehicles are configured to optimize operating efficiency given the load carrying and operational requirements for that vehicle. The model is benchmarked to historical market penetration data obtained from the 1987 TIUS for new energy conserving technologies including: radial tires, aero-dynamic devices, and fan clutches.

Given the assumption that buyers order vehicles that optimize operating cost efficiency, the HDMP model calculates market penetration based on the cost effectiveness of the new technology. Cost effectiveness is measured as the cost of the new technology less the discounted expected energy savings of that technology over a specified time period.

Initial research has also revealed that most heavy and medium duty truck owners and operators are very risk adverse. Therefore, the model incorporates a technology acceptance factor which is intended to restrict unlikely large increases in market penetration of new technologies. As the market share of the new technology increases, the technology acceptance factor is adjusted endogenously to reflect a greater willingness to assume the risks of the new technology.

ENERGY AND ENVIRONMENTAL BENEFITS ANALYSIS

Once estimates for new car and heavy truck market shares were available, it was possible to develop estimates of overall energy, petroleum use, and environmental (criteria pollutant) emissions changes for the period spanning 1995 through 2020. These estimates were generated using two models: the Integrated Market Penetration and Anticipated Cost of Transportation Technologies model and; the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model..

IMPACTT was used to estimate the oil displacement and emissions reduction potentials of each of the advanced technologies evaluated (Ref. 7). The model calculates the effect of alternative vehicle characteristics and market penetration assumptions on baseline fuel use and emissions, and generates summary estimates of the value of oil displaced, emissions reduced, and total marginal capital costs borne by vehicle purchasers. Estimates are based on exogenous projections of conventional vehicle sales, market sales, and the characteristics of new conventional, and advanced technology vehicles.

Vehicle characteristics include: fuel efficiency, emissions of nitrogen oxides, carbon monoxide, hydrocarbons, and sulfur oxides; and incremental capital cost (i.e., the difference between the advanced technology vehicle cost and conventional vehicle cost). Petroleum displacement and emissions reductions are calculated as a function of the projected miles traveled, and the difference between the petroleum use and emissions of conventional vehicles and comparable projections for advanced technology vehicles that are projected to replace those vehicles.

Each technology is modeled using a common approach. First, the vehicle stock and miles traveled by the advanced technology vehicles are determined, then this information is combined with efficiency estimates to develop fuel use and oil displacement. Fuel use changes are relative to consumption by conventional technology vehicles. The final step of the analysis calculates the emissions reduction associated with the advanced technology.

The vehicle stock and usage module is based on a capital vintaging model developed by Greene and Rathi (Ref. 8). The module calculates vehicle stock, annual miles traveled, and fuel displaced. New vehicle sales, market penetration rates, and scrap value are the key determinants of vehicle stock in each forecast year. Vehicle stock by vintage and an age-dependent utilization rates are the major determinants of vehicle use. Fuel displacement is computed based on the sum of the projection of vehicle use and conventional versus alternative vehicle fuel economy for each vintage. Comparable stock and usage projections for heavy-duty vehicles are produced within the model by applying historical survival and usage rates.

The effect of energy use includes estimates of the quantity of gasoline (or diesel fuel) displaced by the use of an alternative-fueled vehicle and the quantity of alternative fuel consumed (e.g. KWH used by electric vehicles). Gasoline displacement is calculated from age-specific vehicle miles traveled and on-road miles per gallon for that age vehicle. Technology specific parameters such as gasoline-equivalent fuel efficiency, and conversion efficiency values are used, as appropriate, to compute alternative fuel consumption.

Energy use reductions due to OTT-supported advanced light duty vehicle transportation technologies are summarized in Exhibit 6 below. Consistent with the requirements of Quality Metrics, both primary energy displaced and primary oil displacement are shown in the table. It can be seen that the total oil displacement that will occur in the year 2020 is 2.8 mmb/d.

EXHIBIT 6:

ENERGY DISPLACEMENT RESULTS (mmbd)

Technology	Primary Energy Displaced			Primary Oil Displaced		
	2000	2010	2020	2000	2010	2020
CNG/LPG Vehicles	0.00	0.00	0.00	0.04	0.11	0.06
Alcohol Vehicles	0.01	0.41	0.60	0.01	0.41	0.60
Electric Vehicles	0.01	0.10	0.08	0.01	0.13	0.10
Fuel Cell Vehicles	0.00	0.04	0.39	0.00	0.04	0.39
Heavy Duty Vehicles	0.00	0.20	0.65	0.00	0.20	0.65
Hybrid Vehicles	0.00	0.50	0.82	0.00	0.50	0.82
Advanced Diesel Vehicles	0.00	0.11	0.12	0.00	0.11	0.12
Aluminum Vehicles	0.00	0.09	0.10	0.00	0.09	0.10
Total	0.02	1.43	2.75	0.06	1.57	2.84

Source: Quality Metrics Analysis (John Maples, University of Tennessee, February 1996)

The last component of the IMPACTT model estimates the reduction in NOx, SOx, CO, and HC emissions associated with advanced-technology vehicles. GREET was used for evaluating emissions of criteria pollutants and greenhouse of various vehicle technologies on a full fuel-cycle basis (Ref. 9). GREET calculates the energy consumption of a fuel cycle by taking into account the amount of energy consumed in each of the stages involved in the fuel cycle. Calculation of emissions for a particular stage are estimated in grams per mmBtu of fuel throughput from the stage. The calculation of emissions takes into account combustion of process fuels, leakage of fuels, fuel evaporation, and other emission sources.

Emission rates (in grams per mile) are modeled as a function of vehicle age for light-duty vehicles, thereby accounting for emissions deterioration as vehicles age. Constant emission rates are assumed for vehicles age five (5) years and under. Emission rates are increased by a uniform rate for each of the years between six (6) years and ten (10) years of age. Emissions generation rates are assumed to remain constant after age ten. Emission reduction rates per mile by age of vehicle are obtained by determining the difference between the advanced and conventional technologies.

The difference between values are multiplied by vehicle miles traveled and converted to short tons. Exhibit 7 illustrates the criteria emission reductions for each of the advanced technologies. Note that Heavy Duty Vehicles are significant contributors to NOx reductions. This is due to the significant efficiency and emissions reductions improvements anticipated from the advanced engine technologies in this sector.

EXHIBIT 7:

EMISSIONS REDUCTIONS ESTIMATES (1000 tonnes)

Technology	Year 2010			Year 2020		
	NOX	CO	HC	NOX	CO	HC
CNG/LPG Vehicles	3.4	258.9	37.5	1.6	120.4	16.8
Alcohol Vehicles	-32.5	359.7	66.3	-44.3	289.0	78.8
Electric Vehicles	47.6	694.4	58.6	39.1	553.4	56.1
Fuel Cell Vehicles	3.9	65.3	6.9	82.7	1,419.3	130.0
Heavy Duty Vehicles	96.9	NA	NA	318.8	NA	NA
Hybrid Vehicles	44.0	9.9	14.0	75.3	16.9	24.0
Advanced Diesel Vehicles	-47.9	1,065.4	71.9	-95.3	1,624.9	114.4

Aluminum Vehicles	7.6	1.7	2.4	9.0	2.0	2.9
Total	122.8	2,455.4	257.7	386.9	4025.9	423.0

Source: Quality Metrics Analysis (John Maples, University of Tennessee, February 1996)

Emission reductions for electric vehicles are based upon work by Wang and Santini which shows that electric vehicle emissions will vary substantially as a function of driving cycle and power plant fuel mix (Ref. 10). For this analysis, it was assumed that electric vehicles would penetrate in cities where they had the most environmental benefit. Since Los Angles and New York City are the most likely sites for initial electric vehicle market introduction, Wang and Santini's results for those cities were combined to produce a composite estimate of initial electric vehicle emissions reduction by vehicle age. These emission coefficients were input into the IMPACTT model.

In addition to short tons, the dollar value of the emissions reductions are reported. Unit dollar values are those recommended by the EPA (Ref. 11), except in the case of electric vehicles. Based on current plans of various states, it is assumed that electrics are only introduced in metropolitan areas with significant air quality problems. Consequently, the value of emissions reduced by electric vehicles is estimated to be higher.

CARBON DIOXIDE BENEFITS ANALYSIS

The OTT Program Analysis and Assessment Methodology includes estimating reductions in carbon emissions from the commercial utilization of OTT-sponsored technologies. Estimates of carbon emission reductions are calculated by comparing carbon reductions from petroleum fuel displacement to carbon emissions from alternative fuel use. Total fuel displacement and use values are multiplied by carbon coefficients provided by the Energy Information Administration (Ref. 12). Estimated carbon emissions reductions are indicated in Exhibit 8.

EXHIBIT 8:

CARBON REDUCTION ESTIMATES

Technology	Carbon Reductions (mmtons)		
	2000	2010	2020
CNG/LPG Vehicles	0.23	0.81	0.49
Alcohol Vehicles	0.57	15.75	18.88
Electric Vehicles	-0.06	0.44	0.45

Fuel Cell Vehicles	0.00	2.11	20.91
Heavy Duty Vehicles	0.10	8.50	27.45
Hybrid Vehicles	0.00	20.27	33.80
Advanced Diesel Vehicles	0.00	4.05	4.43
Aluminum Vehicles	0.00	3.59	4.01
Total	0.83	55.51	110.42

Source: Quality Metrics Analysis (Compiled by John Maples, U.T., February 1996)

ECONOMIC BENEFITS

Currently, the structure of the Quality Metrics Performance Measures and Strategic Principals activity results in economic benefits being quantified by non-OTT parties. In the past, OTT was responsible for generating the economic impacts of the technology programs. As a result, the AMIGA model was developed to estimate impacts on gross domestic product, and jobs by industry sector and technology type (Ref. 13). Recent analytical efforts have continued to rely on the use of the AMIGA model.

SUMMARY AND OBSERVATIONS

The planning and analysis process used by the Office of Transportation Technologies was initially developed in conjunction with the EPACT Section 2021 mandate to develop a five-year Transportation R&D plan. Key methodology elements included: involvement of key program staff in strategic direction, the use of a variety of analytical tools to quantify market penetration and impacts, attention to technology cost analysis and peer review by industry and other agencies. This process is continually improved as new analytical issues are addressed in Quality Metrics analyses.

In the spirit of an on-going process, technical analysis areas that have received considerable developmental attention since 1994 include the following:

- Enhancements to market penetration analysis models (i.e. adding four vehicle size classes, and implementing new national consumer coefficients),
- Continuing life-cycle cost analysis, and assessments for non-personal use (fleet) LDV markets, and fuel/technology choices for heavy-duty transportation markets.

For future analysis, OTT will incorporate the use of several new models including: the Advanced Vehicle Simulator (ADVISOR) model, the Transitional Alternative Fuels and Vehicles Model (TAFVM), and the Greenhouse Gas Accounting Model.

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